THE USE OF RENEWABLE ENERGY SOURCES TO PROVIDE POWER TO CALIFORNIA'S HIGH SPEED RAIL

Presented to

THE CALIFORNIA HIGH SPEED RAIL AUTHORITY

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Presented by

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Executive Summary

The California High-Speed Train (HST) represents a tremendous opportunity for California to meet its greenhouse gas reduction goals by removing cars from the road and by slowing demand for additional air travel. By 2030, HST would remove 12 billion pounds of CO2 annually by reducing air and auto travel. However, the train also would use a significant amount of electricity; by 2030, it would require 3,380 GWh annually, or nearly 1% of the state's electrical load. Assuming the state's current mix of fossil fuel and clean energy, the HST system's electricity use would generate slightly over 5 billion pounds of CO2 per year by 2030.

In order to further increase the GHG benefits the of the High Speed Train, the Transportation and Land Use Coalition (TALC) and other environmental organizations requested the California High Speed Rail Authority (CCHSRA) to study the feasibility and potential costs of powering the train using electricity from clean, renewable resources.

The CCHSRA commissioned this report to investigate the feasibility of powering the HST on clean, renewable energy. In addition to technical feasibility and cost, the report discusses various institutional and/or legal complexities that must be addressed to achieve this renewable goal.

Feasibility

The HST is initially estimated to use 1,150 GWh/yr of energy to transport 30.75 million customers in 2020, and to expand that amount to 3,380 GWh/yr and 94 million passengers by 2030 when the entire system is complete and running at full service levels. Generating this amount of energy from renewable sources should be well within the capabilities of the state. Several studies by various parties, such as the California Public Utilities Commission (CPUC), the Western Governor's Association (WGA) and the Renewable Energy Transmission Initiative (RETI) have consistently concluded that the renewable energy potential for California and the West is substantial. Assuming transmission issues to access these potential resources are adequately resolved (as is the purpose of such organizations as RETI); there should be enough renewable energy available for California and the HST to reach its clean energy goals.

Cost

The forecasted cost, on a per passenger basis, of incorporating a renewable energy strategy seems minimal. Three scenarios were used to compare potential costs of renewables versus a standard energy mix: 1) A 100% wind scenario; 2) A 100% solar scenario; and 3) A 80/20 Wind/Solar scenario were investigated. On top of the $80/MWh utility costs, wind premiums are projected to be at about $17/MWh and solar premiums are projected to be at about $129/MWh. Given the large projected passenger base of 30-94 million passengers, using some stochastic modeling, the added cost of a wind portfolio is projected at $0.86/passenger. Renewables could obviously become cheaper than this projection, relative to natural gas, if trends from the past few years continue.

Institutional Issues

Availability and cost issues do not appear to be major impediments, investigation into the institutional barriers show this area to be more complex and challenging. Generally, it is not simply a matter of buying green energy from a supplier and having it delivered to the train for use. Legislation and regulatory rules restrict the customer-utility relationship in many ways, which would complicate matters for the CHSRA as it deals with several utilities at once. The HST's relatively stable and large demand for energy, however, should make it an excellent customer for the utilities or retail sellers of renewable energy.

The CHSRA could incorporate several methods to address some of these institutional issues.

Retail Access – California has incorporated retail access at various times, whether it is in the form of Direct Access or Customer Choice Aggregation. The HST could implement retail access, allowing it to have control over the price and content of its energy, if certain legal restrictions are relaxed. As it stands, the HST would not be able to simply purchase energy and have it delivered by the various utilities.

Utility Green Energy Options – Some utilities offer the option to purchase green energy directly from them. However, this is not universally available, most notably the large IOUs do not have green energy options.

Voluntary Wholesale Agreements – The CHSRA could procure its own energy from renewable resources and negotiate on an individual basis with each utility to have them receive the energy and offset the HST usage. This would probably be the most administratively complicated, but could be part of larger strategy involving many of these options listed.

Behind the Meter –The CHSRA could create a distributed generation system "behind-the-meter" in which the CHSRA would create and deliver the energy to itself using primarily photovoltaics and small wind energy generators. This might not be entirely feasible at this time, given the size and scope of the HST system and the associated cost of distributed generation.

Use of Renewable Energy Credits (RECs) – A final option is to supplement the strategies above by purchasing the green attributes of generated power with RECs. RECs offer the advantage of allowing the CHSRA to act independently of any of the utilities. The REC market is now small, but should grow over time as utilities take advantage of its possibilities. This, however, is the least direct of the options.

Conclusion

Integrating renewable energy into the HST project would be neither cost- nor resource-prohibitive and would be well in line with the more sustainable future that California is trying to ensure for itself. The benefits in this regard are clear and, with several avenues to "green" the train, the CHSRA could achieve the goal of low-cost, efficient and clean travel. Still, all of these methods except Renewable Energy Credits require potentially complicated institutional arrangements. This is further complicated by the fact that the train's route takes it through approximately a dozen different electric utilities. Some options would require changes to the current marketplace through legislation or greater maturation of markets.

That is why adopting a clean renewable energy policy should include some flexibility and focus on macro-level generation and consumption of energy for the project as a whole. Adopting this policy and gaining the proper expertise early in the design process will allow time for these institutional arrangements to be solidified; allowing the CHSRA to confidently implement a plan for 100% clean renewable energy.

I. Introduction

California has put itself at the forefront of energy policy by passing legislation to help develop a cleaner, more sustainable future. Most importantly, the state has instituted Renewable Portfolio Standards (RPS) which mandates a certain amount of renewable energy be used in electricity generation, and the state passed strong, enforceable legislation aimed at reducing California's greenhouse gas (GHG) emissions.

At the same time, the proposal for a statewide High-Speed Train (HST) has proceeded through a detailed planning phase, and a bond measure to fund the HST is currently on the November 2008 ballot. The HST would reduce pollution and GHG emissions by reducing the growth in automobile and plane travel. These benefits would be somewhat reduced if the HST consumes a significant amount of energy derived from fossil fuels.

The California High Speed Rail Authority (CHSRA) commissioned this report to investigate the feasibility of powering the HST on clean, renewable energy. Bringing together the worlds of clean energy and clean, fast transportation would again set California apart as an innovative leader, while helping to meet urgent state goals for reducing global warming pollution. This report explores three primary issues: 1) Would renewable generation be available? 2) How much would it cost? 3) What are the institutional and/or legal impediments to this policy? The report is divided into the following sections.

Section II of this report discusses relevant California energy policy, specifically legislation mandating GHG reductions and legislation mandating the use of renewable energy resources for electricity usage within the state. The section then discusses how the HST's energy usage and its potential renewable requirements would fit into the state as whole.

Section III then discusses the various renewable technologies available, including their availability and limitations, the development costs, and the future outlook of these resources. This report focuses on the four main sources of clean renewable generation: wind, solar, geothermal, and biomass/biofuels, while briefly looking at other potential and emerging renewable technologies

Section IV analyzes the costs and other considerations that would determine whether or not renewable energy could be a viable alternative for the HST. A model is derived that compares the projected cost of renewable energy with the cost of receiving energy strictly from the various utilities. We look conservatively at three cases to determine the potential costs as compared to reliance on conventional energy: 100% wind, 100% solar, and a mix of the two.

Section V discusses the critical issue of how the CHSRA might actually implement a policy of using 100% renewable electricity to power the HST system. The HST weaves its way throughout California and intersects with many jurisdictions and many energy utilities, which creates some logistical difficulties for the CHSRA in implementing a policy of using renewable energy to power its trains.

Finally, **Section VI** provides conclusions about the overall viability of pursuing a clean, renewable energy policy and suggests next steps if such a policy is adopted.

II. Renewable Energy in California

California is at the forefront of the green energy revolution. No state is more aggressive in adopting policies to create a greener, more sustainable future. California has the most aggressive Renewable Portfolio Standard for reducing reliance on fossil fuels for the state's electricity needs. The state also has enacted the first-in-the-nation legislation designed to reduce the emission of greenhouse gasses.

A. RPS and GHG Goals

1. Greenhouse Gas Emissions (GHG)

The California Global Warming Solutions Act of 2006 (AB32) mandates that California reduce its greenhouse gas emissions to 1990 levels by 2020. In order to meet this goal California will need to reduce its greenhouse gas footprint by approximately 29 percent below currently projected GHG levels for 2020.[1] It is estimated that, for today's mix of electricity generating sources, every megawatt-hour (MWh) of zero-emission electricity generation offsets on average 500 pounds of CO_2. Electricity consumption represents about 28% of greenhouse gas emissions in the state and is increasing every year. In order to meet the GHG standards it is going to be necessary to meet existing and new electricity demand with a greater share of green sources that produce little to no greenhouse gasses and with increased energy efficiency.

2. Renewable Portfolio Standard (RPS)

In 2002 California passed into law SB 1078 which established a Renewable Portfolio Standard (RPS) with the goal that 20% of the state's electricity consumption should come from renewable resources by 2017. This goal was accelerated to 2010 in SB 107. The Governor, the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC) have all endorsed an enhanced target of 33% by 2020. This target is easily the most aggressive in the nation and represents a considerable challenge given the state's growing electricity demand.

Guide to Energy Units

1 Watt: The unit of power. One watt means that one joule of energy is used per second.
1 Kilowatt (kW) = 1,000 watts
1 Megawatt (MW) = 1,000 kW
1 Gigawatt (GW) = 1,000 MW

A **kilowatt-hour (kwh), Megawatt-hour (MWh)** and **Gigawatt-hour (GWh)** represents the average energy used during a full hour. For example a 10 MW power plant could produce 10 MWh of energy if run at full power for one hour.

B. State-wide energy usage

In 2007, Californians used 274,000 Gigawatt-hours (GWh) of electricity. According to the CEC energy demand will increase to 313,671 GWh by 2018, representing an annual increase of 1.2%.[2] At that rate state-wide demand will

[1] California Energy Commission 2007, *2007 Integrated Energy Policy Report*, CEC-100-2007-008-CMF, p. 1.
[2] California Energy Commission, *California Energy Demand 2008-2018 Staff Revised Forecast*, CEC-200-2007-015-SF2, p. 38.

increase to over 361,000 GWh by 2030. The state will need to procure 70,000-120,000 GWH of its annual energy supply from renewable resources to meet the 20-30% RPS requirements.

California electric use peaks during the summer months when demand, increased from the use of air conditioning, is highest. In the summer the peak tends to occur during the mid-afternoon hours between 3-5 PM. In the winter the peaks occur later in the evening between 7-9 PM.

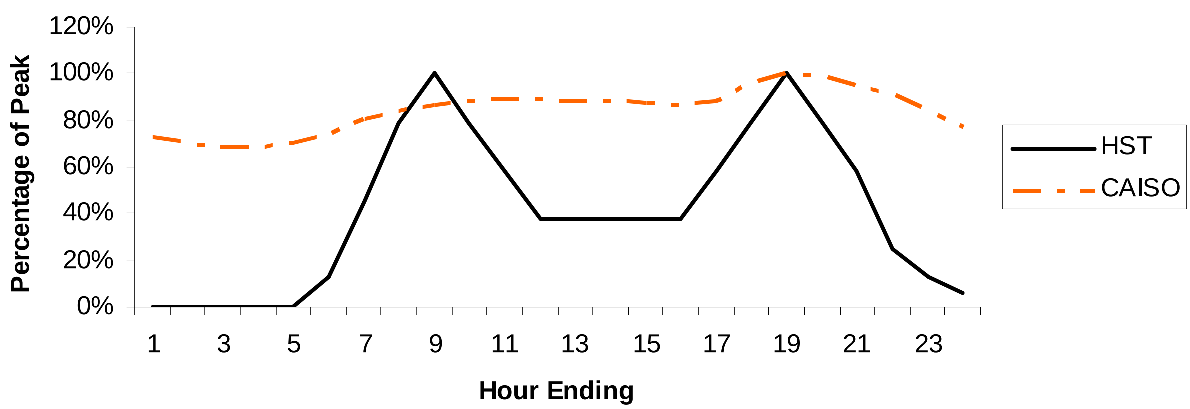
C. HST Energy Usage

The HST is expected to use approximately 3,380 GWh per year by 2030[3] and will serve approximately 94 million passengers per year. This represents only 0.9% of the projected statewide load in 2030. However, if HST were powered by clean renewable energy it would represent 2.8%-4.8% of the RPS renewable needs for the entire state of California.

The daily use trends for the HST are of interest as they imply which type of renewable energy is most suitable to supply the HST and what the costs associated with powering the HST will be. Figures 1 and 2 show that peak usage for the train system will fall between 8-9 AM and 6-7 PM.[4] this shape is significantly different than the general load shape of the California Independent System Operator (CAISO), the organization which oversees the transmission of energy over most of California. It must be noted, however, that while this is the daily load shape for the entire train system, it would not necessarily represent the load used in any single utility service territory.

Figure 1: Average Winter CAISO and HST Daily Load Shapes

Winter 2006



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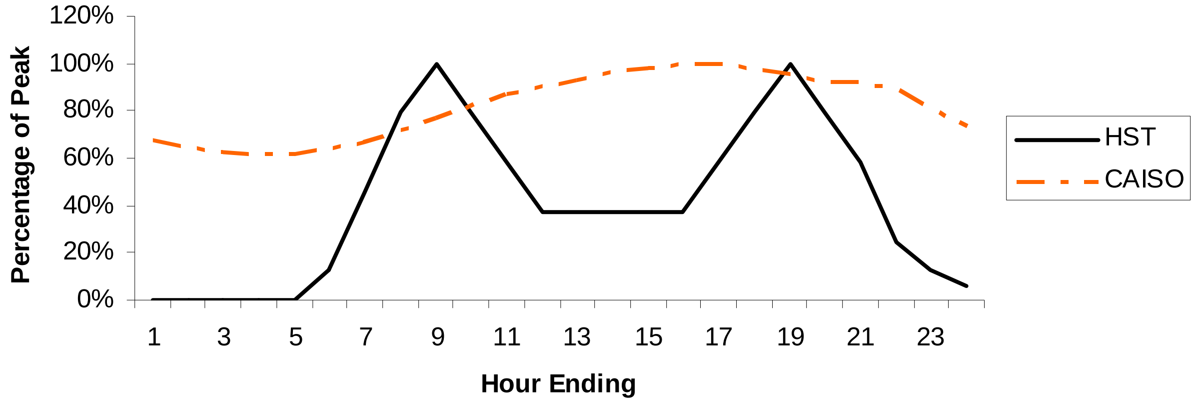
[3] This usage represents usage of the train alone and does not include energy usage at stations or for other purposes.

[4] Usage based only on loads to power the actual trains themselves. It does not include auxiliary usage for stations or other related loads. HST data provided by HSR Authority staff. CAISO data provided by California Independent System Operator staff and based on the report *Integration of Renewable Resources*, November 2007.

Figure 2: Average Summer CAISO and HST Daily Load Shapes

Summer 2006



III. Discussion of renewable energy technologies

Renewable energy for end users can be developed anywhere that conditions allow and the proper transmission infrastructure is in place. If the CHSRA were to implement a renewable energy standard for powering the train, it would need to define the criteria it would use for determining the eligibility of resources to meet the standard. The CHSRA could adopt existing statewide standards used for determining compliance with the Renewable Portfolio Standards or it could adopt its own requirements. Physics of the electric grid dictate that energy from specific generating plants, whether renewable or otherwise, is not delivered directly to end-use customers. The CHSRA's policy might, therefore, only require that it contribute enough new, "additional" renewable power into the grid to offset the amount it is using. This avoids the difficult issues of ensuring deliverability of the renewable energy directly to HST's load points, an aim which could lead to significant inefficiencies and higher costs. Options for implementing renewable policy are more fully discussed in Section V.

Areas of Considerable Technical Renewable Potential

Renewable energy for the HST would likely replace natural gas fired electricity generation that would otherwise be built or operated. The market price of such generation is, of course, highly dependent on the increasingly volatile gas market. Currently, the CPUC sets an annual benchmark for the cost of new renewable energy contracts against the cost of a Combined Cycle Gas Turbine (CCGT) generating plant, known as the Market Price Referent (MPR).[5] The MPR value has increased every year it has been developed, with the baseload price starting at $81.76 in 2005 and rising to $98.40/MWh in 2007 as a baseload price. However, since renewable energy generally has no fuel costs, the operating costs of renewable energy resources are relatively stable. Typical commercial contracts for renewable energy are 20- to 30-year terms at fixed prices, providing a hedge against volatile fuel prices.

A. Wind

1. Description. Wind is considered one of the most promising resources for producing clean energy and is the fastest growing renewable resource (in terms of megawatts) in the United States.[6] California is second in the nation (behind Texas) in installed wind capacity with 1,800 MW currently operating and 5,400 MW of new construction under contract to the Independently Owned Utilities (IOUs.)

The use of wind as a source of energy is limited by when and where it produces energy. This property of wind defines it as an intermittent resource, meaning it cannot be used as a baseload or peaking resource, because the vagaries of the wind to determine when it delivers power. While energy can be produced anywhere the wind blows, cost effective wind installations require strong and somewhat steady and/or predictable wind patterns. However, even turbines in the best wind sites, such as the Altamont or San Gorgonio Passes in California, only produce energy at 30-40% of their maximum capacity on average. Wind resources in California also tend to produce power in the early morning and late evening hours. Figure 3 and 4 show how the typical wind patterns compare to the projected load profile of the HST.

Figure 3: Average Winter Wind and HST Daily Load Shapes

Winter 2006

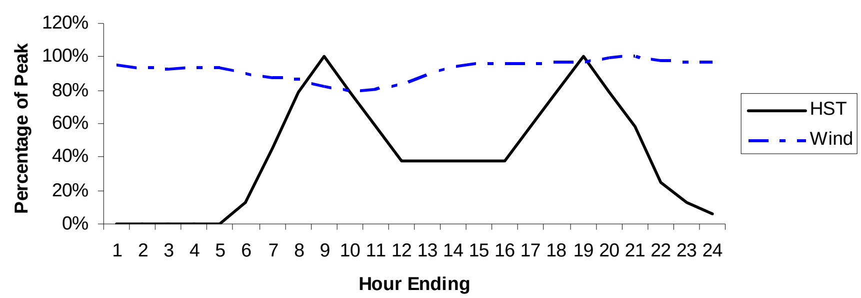
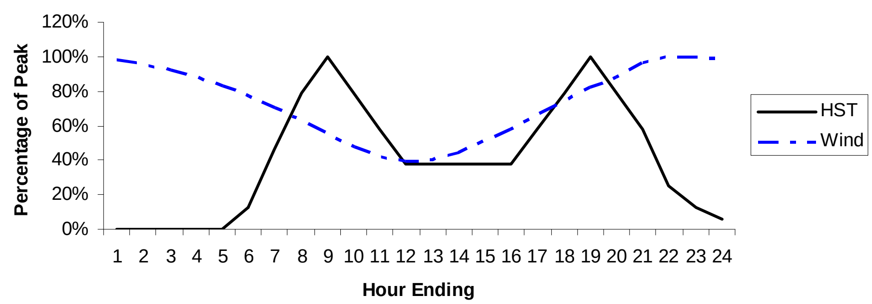


Figure 4: Average Summer Wind and HST Daily Load Shapes

Summer 2006



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[5] The MPR is calculated for various online dates and length of contract. For comparison, a 20 year contract coming online in 2010 is used. The MPR can be found on the CPUC website at http://www.cpuc.ca.gov/PUC/energy/electric/RenewableEnergy/decisions.htm

[6] A megawatt is the capacity, or the instantaneous, production capability of a resource. A 1 MW resource can produce 1 MWh of energy at full capacity over the course of one hour.

2. *Costs.* Despite the disadvantages of wind as an intermittent resource, it is one of the more mature renewable technologies and one of the more cost effective on a dollar per MWh basis. According to a recent report by Renewable Energy Transmission Initiative (RETI) onshore wind is estimated to cost between $59-128/MWh.[7] Wind also currently benefits from the federal production tax credit (PTC). The PTC has been periodically renewed by Congress, but the continued existence of the PTC cannot be assured.

3. *Availability.* The viability of a given region for wind energy production is defined by its class, with a Class 7 region having the most consistent and robust wind patterns and Class 1 being a very poor region for wind. RETI cites the National Resources Energy Laboratory (NREL) estimate of approximately 21,000 MW technical potential of Class 4 or better wind resources in California, with a majority of these existing in the Southern Central California regions in Tehachapi and Mohave. At typical capacity factors this quantity of wind capacity could generate approximately 55,000-75,000 GWh per year. Considerable wind potential also exists farther away in northern Oregon, British Columbia, Wyoming and Montana, which would require considerable transmission upgrades. Options are being investigated just for this purpose by utilities throughout the Western United States.[8]

4. *Looking Ahead.* Wind is currently very competitive with fossil fuels in terms of cost per MWh. In the future, wind is likely to experience upward pressure on prices, as demand increases globally for turbines and as premium land resources are developed. Prices, however, should also face downward pressure as growing global demand provides a catalyst for improved innovation and efficiencies.

Wind suffers primarily in its intermittent character. By not being able to control when the energy is created, wind cannot provide the same direct benefit as on–demand fossil fuel generation, which is available when energy is needed most. In fact, as more and more wind is integrated into the system it can create issues with respect to operating the grid reliably and economically. It also requires dispatchable generation (e.g. natural gas-fired generation) to complement the intermittent wind production. One way to try and combat these issues is through storage. Energy can be stored either through batteries or through hydro or air storage systems. Unfortunately, at this time storage technology is expensive and inefficient.

Another option recently finding greater traction is the development of offshore wind. The wind that blows a few miles offshore is steadier and stronger, in general, than in regions found inland. Technological limitations currently limit access to shallow water sites (20 meters or less). Evaluation by Dvorak et al. estimated that there is a potential capacity of over 3,300 MW of shallow water off shore wind potential off the northern California coast.[9] There is also likely considerable potential in Oregon and farther up the coast, but no evaluation on potential has been done on these areas.

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[7] Report prepared by Black & Veatch for the Renewable Energy Transmission Initiative (RETI), *Renewable Energy Transmission Initiative Phase 1A Draft Report*, March 2008

[8] The Canada/Pacific Northwest to Northern California Transmission Project being developed by six different transmission owning utilities, including PG&E.

[9] Dvorak, M.J., Jacobson, M.Z., Archer, C.L. (2007): California offshore wind energy potential. Proceedings from Windpower 2007: *American Wind Energy Association Windpower 2007 Conference & Exhibition*, June 3-6, 2007, Los Angeles, CA: AWEA.

B Solar

1. Description. Harnessing the power of the sun to create electricity is done in two ways: 1) Concentrating Solar Thermal (CST) and 2) Photo-voltaic (PV). CST is a method whereby the sun's rays are concentrated to create enough heat to power a standard steam turbine. PV, on the other hand, converts the sun's rays directly into electricity. Solar power, like wind, is also considered an intermittent resource since it delivers power only when the sun is shining and is most effective in the summer when the sun's rays are more direct. These limitations allow solar to produce energy only about 20-30% of the time, with CST generally having higher factors than PV. Solar acts more like a peaking resource, meaning that the power, although intermittent in nature, tends to be created during peak periods of the day and year when it is needed most. As Figures 5 and 6 show, this actually means that solar does not match the physical electricity needs of the HST very well.

2. Costs. Solar is the most expensive of the main renewable resources currently running at about $137-176/MWh for CST and $201-276/MWH for PV, according to the RETI report. Solar also benefits from an Investment Tax Credit (ITC) of up to 30% of the initial cost.

Figure 5: Average Winter Solar and HST Daily Load Shapes

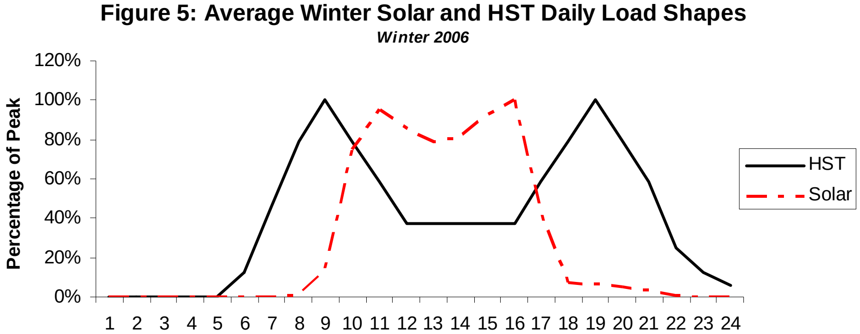
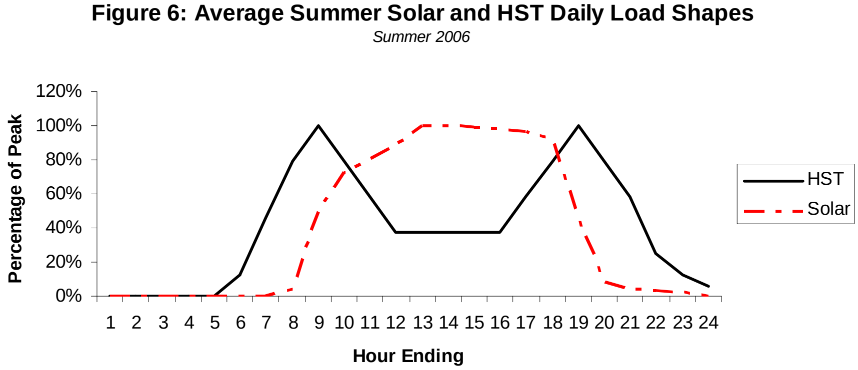


Figure 6: Average Summer Solar and HST Daily Load Shapes



3. Availability. The desert areas of California, Nevada, and Arizona present a tremendous solar potential. This potential is limited in its current development, primarily due to cost and current technologies. Like wind, CST regions are classified by class as to their solar power potential with Classes ranging from 1 (low) to Class 5 (High). The majority of Class 3 or higher CST potential exists in the area of southern California, southern Nevada and western Arizona. Southern California, particularly the Mohave and Imperial Valley areas, have the potential to produce up to 350,000 MW of CST or 600,000-900,000 GWh per year. In Arizona and Nevada the total Class 3 potential is estimated at over 1,000,000 MW, with approximately 500,000 MW of that potential in regions bordering California.

PV offers an even greater potential. A 2005 CEC report estimated that there is almost 17,000,000 MW of technical PV potential.[10] PV benefits from the fact that it is not as limited as CST in its siting requirements to be effective and it can be deployed as a "behind-the-meter" distributed generation application to reduce net energy consumption billed to the customer by the electric utility.

4. Looking Ahead. Solar energy's biggest limitations at this time are its price and, to a lesser extent, its intermittent character. Like wind, the development of better storage technologies would improve the resource's efficiency and economics. While the technology exists to store the heat, it tends to be expensive. Solar energy development is currently seeing a lot of investment developing marketable technologies that are both cost effective and efficient. Compared to the more mature renewable technologies like wind and geothermal, solar is relatively early in its development cycle and is seeing rapid improvements in economy and technology.

C. Geothermal

1. Description. Geothermal energy uses the heat created from under the earth's crust to create steam to power generators. California is the leading developer of geothermal electricity generation, with over 1,800 MW of installed capacity. The Geysers north of San Francisco is the largest geothermal energy producing field in the world at about 850 MW.

Unlike wind and solar, geothermal plants can be used as baseloading resources, delivering energy practically around the clock. However, it is generally not a resource that is available on demand, so energy is delivered at a fairly constant rate for 24 hours a day.

2. Costs. The RETI report estimates that the levelized cost of Geothermal is $54-107 MWh.

3. Availability. California and northern Nevada are considered areas of high geothermal potential. It is estimated that there is an incremental capacity possibility of 2,375 MW of geothermal energy in California (15,000-20,000 GWh per year), with almost 1,900 MW of this coming from the Imperial Valley region in Southern California. Nevada has a potential for over 1,500 MW of incremental geothermal capacity, most of it coming from what is known as the Great Basin region of central and northwestern Nevada. Difficulty in developing geothermal comes from the costs associated with actually locating suitable geothermal resource, which requires of drilling test wells.

4. Looking Ahead. Currently, geothermal energy generally requires temperatures of 300°F to be effective. However, low temperature geothermal systems, working at 165°F, are being researched and developed and show promise to open up more regions for geothermal development.

D. Biomass

1. Description. Producing electricity from natural waste materials takes place primarily in two different ways-- through direct-fired biomass, the burning of waste, and through the capture and firing of gas from decomposing organic materials, either as biogas or landfill gas.

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[10] Simons, George and Joe McCabe, *California Solar Resources Draft Staff Paper*, CEC-500-2005-072-D., April 2005.

Direct-fire uses the basic principle of burning waste much like coal plants burn coal to produce steam to drive turbines or reciprocating engines. However, unlike coal, electricity generated from biomass does not create incremental GHG emissions because the biomass fuel absorbs GHGs while growing and would otherwise create GHGs through its disposal or natural decomposition. Biogas and landfill gas technologies use methane produced by decomposing waste to run gas turbines.

Biomass and biogas energy production is similar to geothermal in that they are considered baseload resources, able to produce energy around the clock, year-round, but they generally are not expected to produce energy on demand. However, stored biomass fuel, most likely biomass-derived liquid fuels such as ethanol or biodiesel, could be used instead of natural gas to back up intermittent wind generation. (Biomass is, in fact, solar energy captured via photo-synthesis in living plants and stored in the woody or other parts of the plant.)

2. Costs. The levelized costs for these technologies range from $50-80/MWh for landfill gas to $67-150/MWh for direct-fire to $100-168/MWh for Biogas, according to the RETI report.

3. Availability. Biomass facilities can be built anywhere that the necessary fuels can be gathered. Forestry and agriculture waste would be a major source of fuel for these facilities and estimates give the potential to build almost 5,000 MW (30,000-40,000 GWh per year) of biomass in California. This would consist of many distributed, small plants throughout the state.

4. Looking Ahead. Biomass will likely be a vital part of the energy future of California. As transmission access is expanded more and more facilities should be available and better technologies should be developed to bring even more biomass energy into the mix.

E. Other

One other major resource that is well matured is small hydro energy sources. There is some potential for new or incremental small hydro to be developed. However, small hydro is limited as a new energy source in California due to environmental concerns surrounding its development.

Given the current appetite for renewable energy it is not surprising that new technologies are being developed all the time. Turbines powered by tidal currents and ocean waves are in their infancy, but offer tremendous potential. Fuel cells that use the chemical properties of hydrogen, the most abundant resource on the planet, to create clean electricity are also being developed to try and make them more efficient and economically viable. This report did not explore this option since hydrogen is often derived with the use of fossil fuels, and this report focuses on large scale renewable resources.

IV. Renewable Energy and HST

A. Cost of renewable energy compared to standard power rates

This section compares the projected cost of acquiring power from the various electrical utilities and the cost of acquiring energy via renewable sources. It also analyzed potential cost differentials per ticket. An electric utility rate was derived based on a weighting of energy rates from the three Investor Owner Utilities [Pacific Gas & Electric (PG&E), Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E)], as well as Los Angeles Department of Water and Power (LADWP), Sacramento Municipal Utility District (SMUD), and Modesto Irrigation District (MID). The weighting was approximated by the share of line miles going through each territory. The weighted average electric utility rate was assumed to grow at a stochastic (random) rate, normally distributed around 2% and with a standard deviation of 2%.

Renewable energy rates were calculated as market price based on the cost of gas-fired generation with a 9,500 Btu/kWh heat rate with a green premium added onto it.[11] The green premium was allowed to fluctuate about a normal distribution with the mean of $17.00 /MWh for wind and $129/MWh for solar, in order to give a good high and low in the range. These numbers include a $5/MWh firming cost, i.e. a cost to compensate for the intermittent character of the resources. Table 1 shows the various rates used in the modeling. An additional case with a mix of 80% wind and 20% solar was also evaluated.

This approach relies on assumptions about current renewables costs and technologies. There is reason to believe that the premium paid for renewable energy would decrease over time. Economies should be seen due to increased demand in renewables worldwide. Greater investment, both public and private, should result in improvements in efficiency and costs.[12] On the other side of the ledger, natural gas is the primary fuel for new generation in California. While it does not track to the price of oil directly, it is affected by the general trend of energy prices. As recent experience with oil prices suggest, the trend is quite variable and generally shifting upward. One benefit of renewable energy would be the stability of its cost profile, unlike utility rates that are tied closely to natural gas.

[11] Heat Rate refers to the efficiency with which natural gas is converted to electric energy. In this case, 9,500 Btu/kWh is used to represent a "market" heat rate, or the marginal cost of producing electricity with natural gas generation.

[12] A 2007 UN report outlined $100 billion in renewable and energy efficiency investment in 2006, while New Energy Finance estimates that to be almost $150 billion in 2007. Another example of private investment in renewable energy R&D is Google's RE<C initiative, an initiative by Google to fund research into development of renewable energy with the goal of making renewable energy less expensive than coal.

Table 1: Utility and green energy costs

	2020 $/MWh	Green To Market Premium	Green to Utility Premium
Wind	$96.97	$17.00	$22.41
Mixed	$119.36	$39.39	$44.80
Solar	$208.94	$128.97	$134.38
Market Energy	$79.97		
Utility Generation Rate	$74.56		

A Monte Carlo simulation with 1,000 iterations was run to determine a distribution of possible future outcomes of the $/MWH difference. This is also presented graphically on an expected cost per ticket basis. Energy usage of the train is expected to ramp up as various phases are included and as ridership increases. Table 2 shows the annual energy and ridership assumptions used. See Appendix A for more detail on the modeling assumptions.

Table 2: Energy usage and ridership schedule

Year	Customers (millions)	Energy (GWh)
2020	30.75	1,150
2021	33.78	1,263
2022	37.11	1,388
2023	40.77	1,525
2024	44.79	1,675
2025	65.45	2,380
2026	70.11	2,544
2027	75.24	2,724
2028	80.88	2,922
2029	87.11	3,140
2030	94.00	3,380

Wind Case. This case of using 100% wind brackets the costs on the low end, but given how the load shape for the HST matches wind fairly well, this case is probably far closer to a likely case, Figure 7 below, shows the distribution of wind premium over the utility rate over the 2020 – 2030 period. The average premium for wind over the utility rate is $23.61/MWh with a standard deviation of $31.71/MWh. Figure 8 translates that into a cost per ticket, or an additional 86 cents on average per ticket with a standard deviation of $1.16.[13]

Figure 7: Wind cost premium above utility rates

Blue bars represent 95% of cases

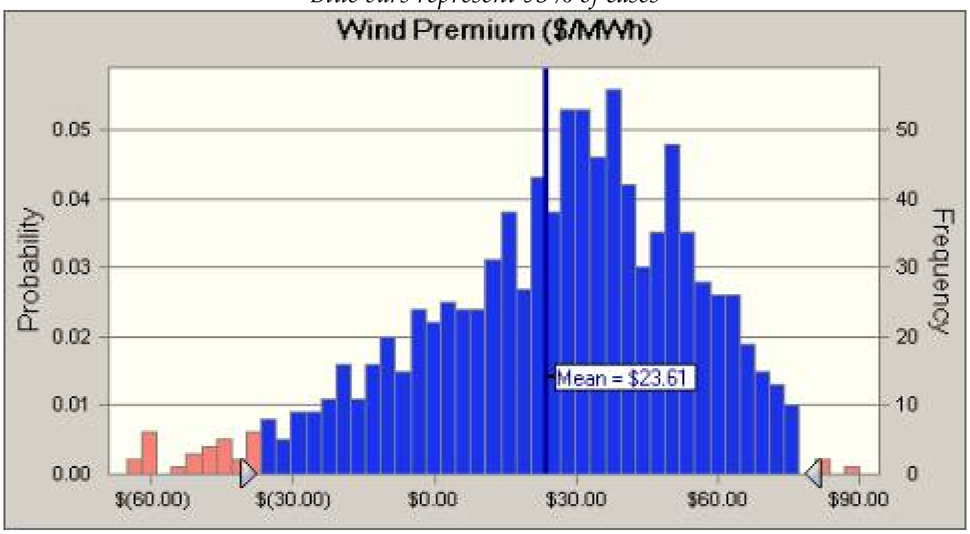
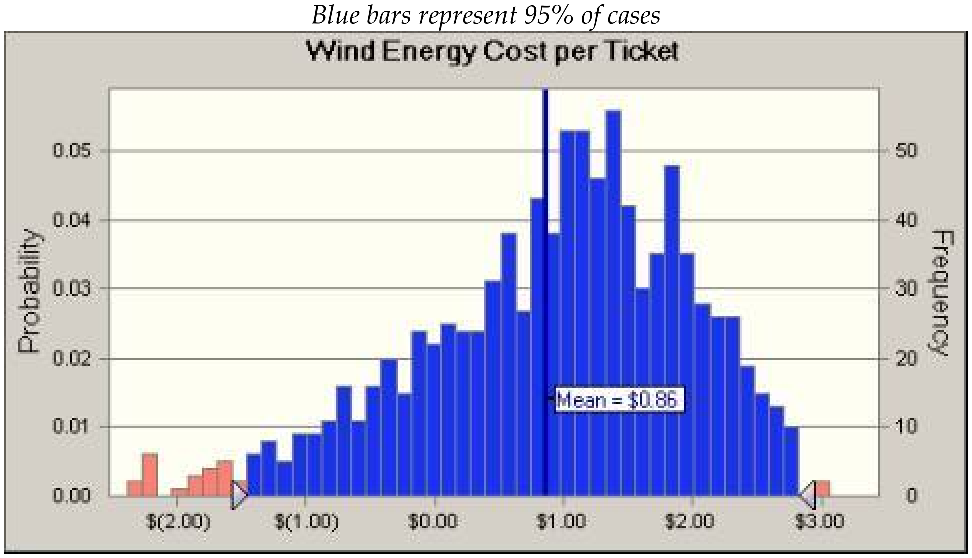


Figure 7: Wind cost premium above utility rates

Blue bars represent 95% of cases



[13] This costs represents an average cost per ticket regardless of the length of trip, in practice, longer trips would incorporate more of the premium into its price and shorter trips less.

Solar Case. This case of using 100% solar brackets the costs on the high end, as an extreme high or limiting case. Figure 9 below, shows the distribution of the solar energy premium over the utility rate over the 2020 – 2030 period. The average premium for the mixed wind/solar case over the utility rate is $134.84 with a standard deviation of $40.51/MWh. Figure 10 translates that into a cost per ticket, or an additional $4.92 on average per ticket with a standard deviation of $1.48.

Figure 9: Solar cost premium above utility rates

Blue bars represent 95% of cases

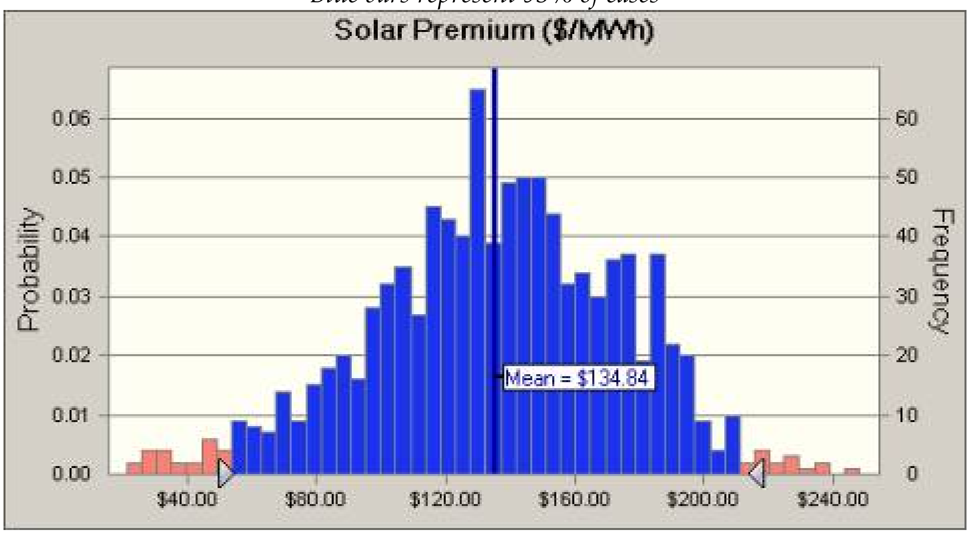
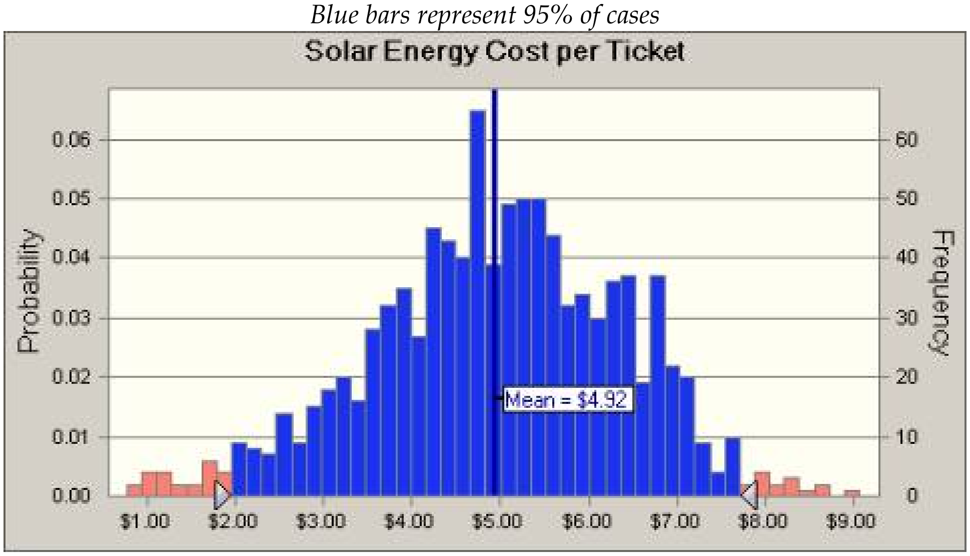


Figure 10: Solar cost premium above utility rates

Blue bars represent 95% of cases



Mixed Case: 80% Wind/20% Solar. To form what may be considered a base case, a mixed portfolio of 80% wind and 20% solar was created. Since wind is less expensive and tends to fit the profile of the train more readily it seems reasonable to think that a portfolio might include considerably more wind than other resources. Figure 11 below, shows the distribution of the mixed resources energy premium over the utility rate over the 2020 – 2030 period. The average premium for the 80/20 mix over the utility rate is $45.92 with a standard deviation of $34.20/MWh. Figure 12 translates that into a cost per ticket, or an additional $1.68 on average per ticket with a standard deviation of $1.25.

Figure 11: 80/20 Wind/Solar cost premium above utility rates

Blue bars represent 95% of cases

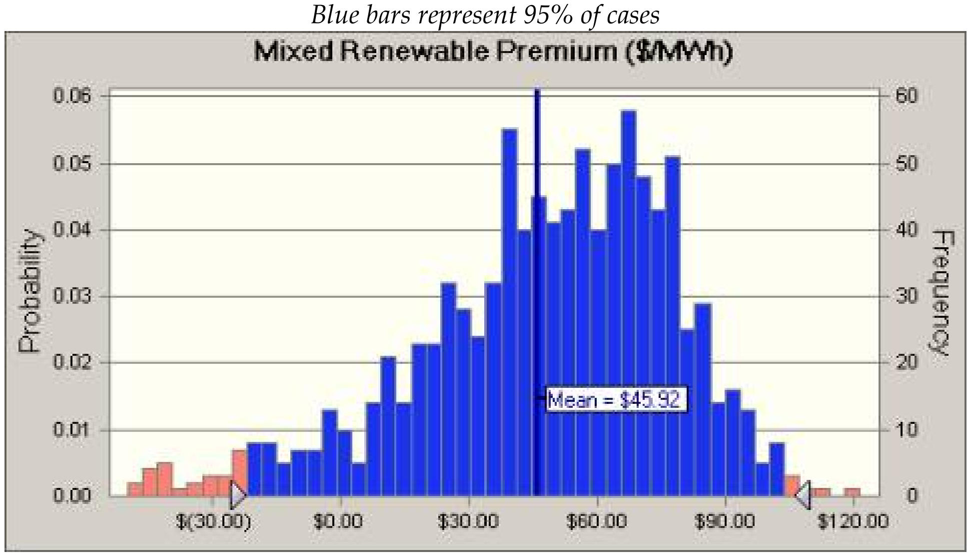
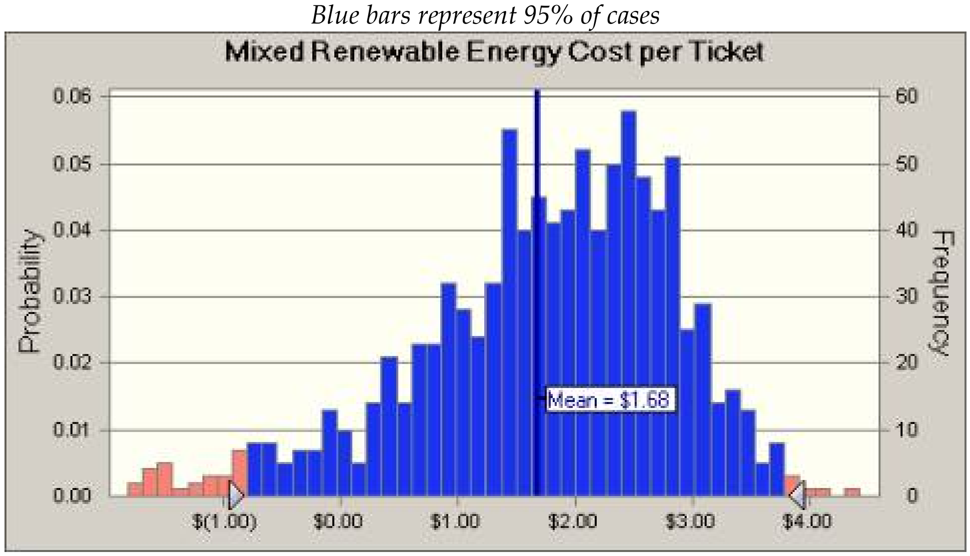


Figure 12: 80/20 Wind/Solar cost premium above utility rates

Blue bars represent 95% of cases



This analysis is not necessarily meant to represent what the actual composition of the renewable energy used by HST would be. These three cases are meant to present a good indication of the total effect that the acquisition of renewable energy would have on the costs of operating the train. Other resources, such as geothermal and biomass would likely be part of such a portfolio, given their potential and their cost characteristics, they would not have a significant effect on the resulting cost estimates of the 80/20 wind/solar case.

The biomass backup for wind (i.e., the stored biomass mentioned above in III-D), the landfill gas biomass option, and the geothermal option may keep the wind case toward the low end of the cost range, because all of these may add capacity at the low cost end of the renewable options.

V. Institutional Issues

The institutional issue of how the CHSRA would actually go about acquiring a completely renewable portfolio as its own electricity source may prove more complicated than issues of availability and cost. Depending on the configuration of the system -- it is estimated that the route will require energy to be delivered every 30 miles -- the train's route takes it through approximately a dozen different electric utilities. This includes all three major Investor Owned Utilities (IOUs) – PG&E, SCE, SDG&E; and Publicly Owned Utilities (POUs) such as LADWP, SMUD, and the Modesto Irrigation District. The CHSRA thus faces both logistical issues, in terms of the number of utilities, and legal issues, as regulatory rules apply differently to the different entities.

If the CHSRA does not pass a renewable energy policy it would simply be taking its energy from all or some of the dozen or so utilities through which it would pass. It would be reasonable to assume that the energy composition would then reflect that of the statewide portfolio of delivered energy and given the current RPS standards, likely to be 20-33% of all the energy received. With a clean renewable energy policy there would be several institutional arrangements that would likely be available. The preferred strategies may vary depending on the particular utility. The primary options would be:

A. Retail Access
B. Participation in utility green energy options
C. Wholesale Agreements
D. Behind the meter/Distributed Generation
E. Purchase of Renewable Energy Certificates (RECs)

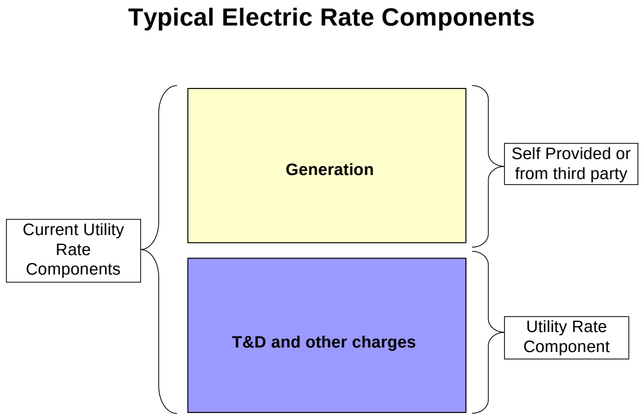
Under any option it should be understood that it is not feasible to physically control the flow of electricity from particular resources to the HST grid connection points. The goal of powering the HST with renewable energy must be measured by the quantity of renewable energy injected into the grid and the quantity consumed by the HST over some defined time period such as a year or a month. Renewable energy production will not match HST loads on an hour-by-hour basis, but should balance over a broader period of time. Costs associated with using the grid to balance hourly demands can be minimized by assembling a renewable supply portfolio with production characteristics that matches the HST load profile as closely as possible.

This policy should ensure that the CHSRA is actually purchasing new renewable capacity, above and beyond what a given utility would have done anyway to meet California's Renewable Portfolio Standard. To do this, utilities that negotiate an agreement with the CHSRA would have to exceed the state's standard by at least as much as the portion used to power the HST.

A. Retail Access

California has developed various methods by which electricity consumers receive the generation part of the power from a source other than their traditional utility. An electricity bill is primarily made up of two pieces: 1) the generation; and 2) the transmission and distribution, or T&D (the wires). As figure 13 shows below, a customer could, in theory, buy its own power and have it delivered by the utility, meaning they still pay the utility for the T&D.[14] This, of course, gives the customer more control both over the cost and the content of their electricity usage, such as, in this case, choosing more renewable resources.

Figure 13: Typical electric rate components



Beginning in 1998, Direct Access (DA) allowed individual customers, or aggregated customers, to receive the generation from a third party, with the utility delivering the power via their transmission and distribution system. One of the reasons many customers switched to DA service was so that they could contract with a provider that would have their energy come from green resources.

DA, however, is indefinitely suspended at this time as a remnant of the California energy crisis in early 2000. However, DA may be reinstated by the time the HST opens in 2020.[15] If this is the case it would probably be a reasonable option for the CHSRA to procure its energy from a third party that would offer a green option. However, the DA option only extends to electricity taken at a point of connection with one of the IOUs. Any electricity taken from a non-IOU entity would not be eligible for DA in its current incarnation.

California does allow an energy option called Community Choice Aggregation (CCA) which allows cities and counties to be the energy provider for their residents and businesses. While there is no current CCA program in California, several communities are into the process of developing such a program, some with the express intent of having a considerable portion of the electricity come from renewable resources. Again, however, CCA only applies to customers of the IOUs and it is generally up to the city or county to determine how much renewable energy should be included in the CCA electricity mix

[14] Figure is illustrative and does reflect the true relative share of energy to the entire rate.
[15] Direct Access can only be reinstated once the Department of Water Resources is no longer the owner of any energy contracts and at this time that would be about 2013. However, PUC is investigating ways to rid the DWR of its contracts and reinstate DA earlier than that.

A potential solution would be for the state to legislate that the HST could be its own energy provider, while still having the power delivered by the utility using a model similar to CCA. Logistically, this would require tariffs or agreements with each individual utility.

The primary advantage of using voluntary retail agreements is that it would allow the CHSRA to purchase its energy from many bidders and select the lowest cost options. Given the size of the project and the relative stability of the load profile, the CHSRA should be a desirable counterparty for any retail seller of renewable power.

B. Participation in Utility Green Energy Options

Many utilities allow their customers to pay a slight premium in order for the utility to purchase green energy. These can vary from to a flat monthly fee to a rate based on usage. However, currently these programs are limited to residential and commercial customers. Examples of such programs are SMUD's Greenergy program (http://www.smud.org/community-environment/greenergy/comgreen.html) and LADWP's Green Power program. This option is not available from all utilities, notably the three major IOUs do not currently have any green energy options and there are no concrete plans in place for them to be offered. The CHSRA may be able to negotiate with individual utilities to create a specific green energy program if one does not exist, but unless legislated, the utilities will be under no obligation to agree to such an arrangement. However, much like the use of voluntary retail agreements, the stability and size of the HST's energy usage would likely make utilities more willing to enter into agreements that allow the train to be served by renewable energy.

If Direct Access is available, the combination of green energy options from POUs that offer them (or could be negotiated) and a Direct Access agreement with a renewable energy provider could be used to green the HST's electricity usage across the board.

C. Voluntary Wholesale Agreements

Another option that could be explored would be for the HST to contract out its own energy supply, in this case from renewable resources, and have the utility integrate the renewable energy into its portfolio and deliver the energy. This works to a degree for government agencies such as BART and Edwards Air Force Base. The basic arrangement is that the utility receives the additional clean power and integrates it into its entire energy portfolio. The providing entity, such as the CHSRA, then receives energy from the utility and is credited for the energy delivered from the resource with which it contracted. This kind of arrangement would not likely be a single solution as it is complicated by the various utilities that would have to be involved, their disperse delivery points, and the different way the HST's load would manifest throughout the day within each service territory. However, since a large majority of the HST's energy would be provided by PG&E, SCE, and SDG&E, reaching this kind of agreement with all or some of these would go a long way toward meeting the train's energy needs with renewable power.

D. Behind the meter

Another option would be for the HST to incorporate renewable power directly into its system behind the meter. By this is meant that the power would be generated directly into the HST system just like a home with rooftop solar PV. This could be done through distributed solar PV, small wind installations, or fuel cells. Given the intermittent character of wind and solar, though, it would be probably be necessary for this energy to be firmed up off the main grid with energy from the utilities, or some other method, like energy storage, that might become more economically viable for distributed resources by 2020.

Wind and solar need appropriate conditions in order to be economically viable, so it is unlikely that either of these options would be adequate along every part of the route. The size of such distributed generation would need to be very large given the HST's energy needs. The state has a goal to add 3,000 MW of rooftop PV statewide through its California Solar Initiative (CSI). The HST alone would require over 600 MW of PV and probably more in order to offset energy needed during early morning and evening hours.

One benefit from distributed generation is that it allows the entity to use Net Energy Metering (NEM), which would allow the HST to offset its energy usage with the energy it generates and is able to return to the grid. This is sometimes referred to as "spinning the meter backward". Energy returned to the grid simply offsets energy used, but the possible implementation of a feed-in tariff would allow renewable generation placed on the grid by small generators to be paid for by the utilities at known rates.

While distributed generation, like PV, could prove useful in powering the train, it is likely not a comprehensive solution. A more likely use for behind-the-meter and/or distributed generation would be to provide electricity to stations and other administrative facilities where conditions allow.

E. Renewable Energy Credits/Certificates (RECs)

RECs allow the producer of renewable energy to separate out the renewable or 'green' attribute of the energy and sell it separately from the power itself. This allows someone to buy or receive their energy from a non green resource such as coal or natural gas fired generation and then purchases an equivalent number of RECs to "green" their energy.[16] The Western Electric Coordinating Council (WECC) has formed a web-based RECs accounting system called WREGIS to insure that renewable attributes are accounted for only once. While WREGIS allows for buyers and sellers of RECs to find each other it is not a trading hub at this time and is meant only to be a central repository for registering and retiring RECs.[17] Currently the CPUC is holding hearings to see how RECs will be accounted for in California's Renewable Portfolio Standard in rulemaking 06-020-12. It is likely that RECs will be allowed for compliance with RPS, at least for renewable resources that are located within the state.

RECs offer the clearest option to greening the energy usage of the HST, as it is a solution independent of which utility is delivering the portion of the energy and the composition of that energy. The downside is that currently there is a very small market for RECs and it is not clear what the availability of RECs will be in the future if and when it may be possible for utilities to use RECs in their RPS compliance. Although it is uncertain what the price would be, one would expect the price of a REC to track the premium paid for green energy. An additional drawback is that many people perceive the purchase of RECs as inferior to the direct purchase of renewable energy (energy bundled with the REC) as a means of demonstrating a renewable energy portfolio.

[16] Whoever receives the actual energy from the renewable resource would not, then, be able to claim the energy as being green.

[17] A REC is *retired* when an entity wishes to take credit for the green attribute, generally for purposes of RPS compliance. Once a REC is retired it cannot be re-sold or traded.

Generally, this option should be seen as a last resort. It may, however, become the most efficient means of closing any gap that remains after the other strategies have been utilized or to use in lieu of gaining energy from utilities that have low levels of renewable potential.

VI. Conclusion

The California High Speed Train represents a tremendous opportunity for California to meet its GHG emission reduction goals by removing cars from the road and by slowing demand for additional air travel. However, the train also would use a significant amount of electricity. By 2030, 3,380 GWh usage of the HST represents an electricity usage even larger than that of the more moderately sized public utilities in the state.

In general, cost trends are leading renewables to be cost-competitive with fossil fuels more quickly than analysts had predicted. Still the CHSRA should consider a policy that allows flexibility given the unlikely event that the premium for clean energy becomes prohibitively large (and could result in significant ridership losses); in such a case, the policy could allow the CHSRA to put somewhat less renewable energy into the grid than it will be using (i.e. not meet the 100% standard).

The CHSRA should decide early on in the development process whether or not they wish to pursue an all-renewable option for the train. If so, it will be necessary to incorporate renewable energy planning into the business and environmental plans of the train. Expertise in renewable energy development is available, and would ensure the CHSRA develops its energy future in a cost effective and environmentally acceptable way. For planning purposes it is best to be committed early to renewable energy.

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Acronyms Used

CAISO: California Independent System Operator
CCA: Community Choice Aggregation
CEC: California Energy Commission
CCGT: Combined Cycle Gas Turbine
CPUC: California Public Utilities Commission
CST: Central Station Thermal
DA: Direct Access
GHG: Greenhouse Gas
GW/GWh: Gigawatt/Gigawatt-hour
CHSRA: High Speed Rail Authority
HST: High Speed Train
ITC: Investment Tax Credit
IOU: Investor Owned Utility(ies)
kW/kWh: Kilowatt/Kilowatt-hour
LADWP: Los Angeles Department of Water and Power
MID: Modesto Irrigation District
MPR: Market Price Referent
MW/MWh: Megawatt/Megawatt-hour
NREL: National Research Energy Lab
PG&E: Pacific Gas & Electric
POU: Publicly Owned Utility(ies)
PTC: Production Tax Credit
PV: Photovoltaic Solar
REC: Renewable Energy Certificates/Credits
RETI: Renewable Energy Transmission Initiative
RPS: Renewable Portfolio Standard
SCE: Southern California Edison
SDG&E: San Diego Gas & Electric
SMUD: Sacramento Municipal Utility District

Appendix A: Modeling Assumptions

The model is based on comparing the projected utility rate with the projected cost of renewable energy.

Utility Rate

The utility rate is forecast based on a base rate and a stochastic growth rate:

$Ut = U_0 \, x \, (1+ R)$

The base utility rate is calculated as a weighted average of utility generation rates from various utilities throughout the proposed route of the HST. The following table gives the various rates and their weighting:

Table A.1: Utility rate weighting

	MID	SMUD	LADWP	SDG&E	SCE	PG&E	
Annual Rate	0.0617	0.0817	0.0628	0.0908	0.0674	0.1066	
Weighting	4%	4%	4%	7%	27%	53%	**Total Annual Rate**
	0.0027	0.0035	0.0027	0.0064	0.0182	0.0565	**0.0900**

The rates have a base growth rate (*R*) of 2%. The base growth rate is a stochastic term that is normally distributed with a mean of 2% and a standard deviation of 2%.

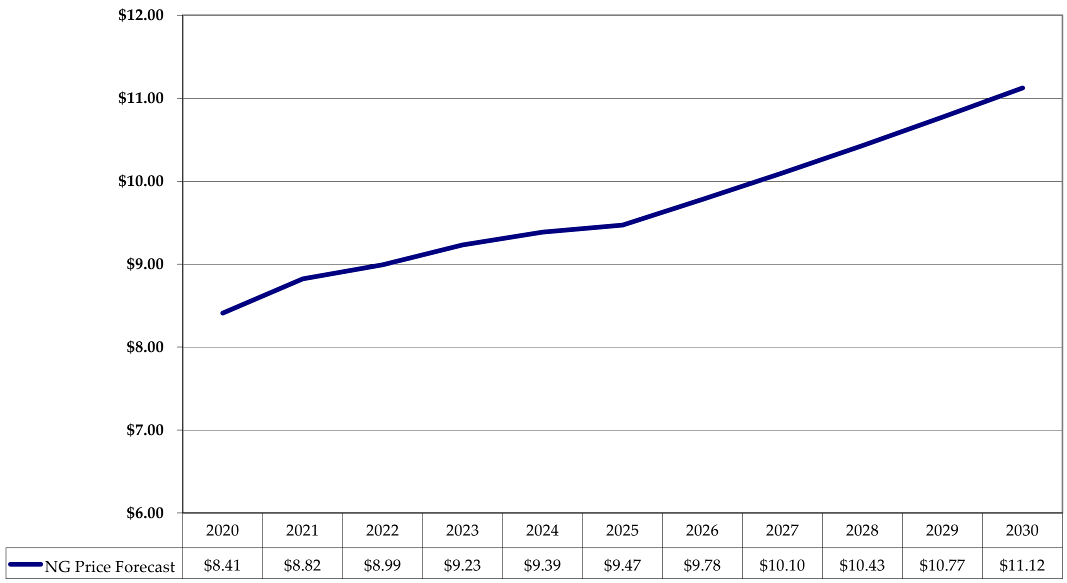
Renewable Energy Rate

The renewable energy rate is based on a market rate derived from a gas price forecast and a renewable premium dependent on the technology that makes up the portfolio:

$Rt = 9.5 \, x \, Gt + P$

The gas price is Navigant's own internal gas price forecast shown in Figure A.1:

Figure A.1: Natural Gas Price Forecast
(2020 - 2030)



The gas price is multiplied by a market heat rate of 9.5 and then a green premium (*P*) is added. The green premium is a stochastic variable with a mean based on the technology and a standard deviation of 20% of that value. Table A.2 gives the assumptions used for Wind and Table A.3 gives the assumption used for solar to determine the premium. No tax incentives are assumed.

Table A.2: Wind plant production assumptions

Wind	$17.00 Premium		
I. OPERATIONAL CHARACTERISITICS:		INPUT	
A. NET PLANT CAPACITY (MW)		600	
C. HEAT RATE (Btu/kWh)		-	
D. AVAILABILITY FACTOR (%)		92%	
E. CAPACITY FACTOR (%)		30%	
F. HOURS OF OPERATION (HRs)		8760	
G. VARIABLE OPERATION AND MAINTENANCE ($/MWh)		$5.50	
ANNUAL ESCALATION OF VOM		1.50%	
H. FIXED OPERATION AND MAINTENANCE ($/KW-Year)		$11.50	
ANNUAL ESCALATION OF FOM		1.50%	
II. COST AND FINANCING ASSUMPTIONS:		INPUT	CALCULATION
A. INSTALLED CAPACITY COSTS ($/kW)		$2,150	$1,290,000,000
B. TERM OF FINANCING (Years)		30	
C. INTEREST RATE (%)		7.00%	
D. OTHER FINANCING: (% of Installed Capacity Costs)			
STARTUP / WORKING CAPITAL		1.0%	$12,900,000
CONTINGENCY		1.5%	$19,350,000
DEBT SERVICE RESERVE FUND	$108,634,501	8.1%	$108,634,501
UNDERWRITING, ISSUANCE, LEGAL, INSURANCE		2.0%	$25,800,000
E. TOTAL COST AND FINANCING SERVICE		12.9%	$1,456,684,501

Table A.3: Solar plant production assumptions

Solar	$128.97 Premium		
I. OPERATIONAL CHARACTERISITICS:		INPUT	
A. NET PLANT CAPACITY (MW)		650	
C. HEAT RATE (Btu/kWh)		-	
D. AVAILABILITY FACTOR (%)		92%	
E. CAPACITY FACTOR (%)		28%	
F. HOURS OF OPERATION (HRs)		8760	
G. VARIABLE OPERATION AND MAINTENANCE ($/MWh)		$1.50	
ANNUAL ESCALATION OF VOM		1.50%	
H. FIXED OPERATION AND MAINTENANCE ($/KW-Year)		$113.20	
ANNUAL ESCALATION OF FOM		1.50%	
II. COST AND FINANCING ASSUMPTIONS:		INPUT	CALCULATION
A. INSTALLED CAPACITY COSTS ($/kW)		$3,900	$2,535,000,000
B. TERM OF FINANCING (Years)		30	
C. INTEREST RATE (%)		7.00%	
D. OTHER FINANCING: (% of Installed Capacity Costs)			
STARTUP / WORKING CAPITAL		1.0%	$25,350,000
CONTINGENCY		1.5%	$38,025,000
DEBT SERVICE RESERVE FUND	$213,479,427	8.1%	$213,479,427
UNDERWRITING, ISSUANCE, LEGAL, INSURANCE		2.0%	$50,700,000
e. TOTAL COST AND FINANCING SERVICE		12.9%	$2,862,554,427

The model was run by the software program *Crystal Ball,* an Excel based simulation platform, as a Monte Carlo simulation. One thousand runs were completed whereby random values for the utility growth rate and the renewable premium were drawn from their respective distributions to help determine the per ticket premium. The resulting runs were then presented with distributions and summary statistics.